Importance and Role of Large Wood in Riverine Ecosystems

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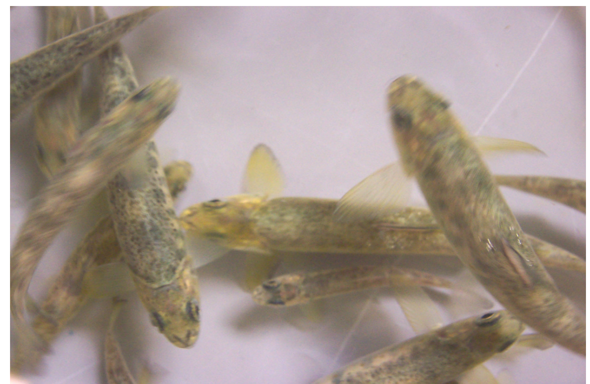
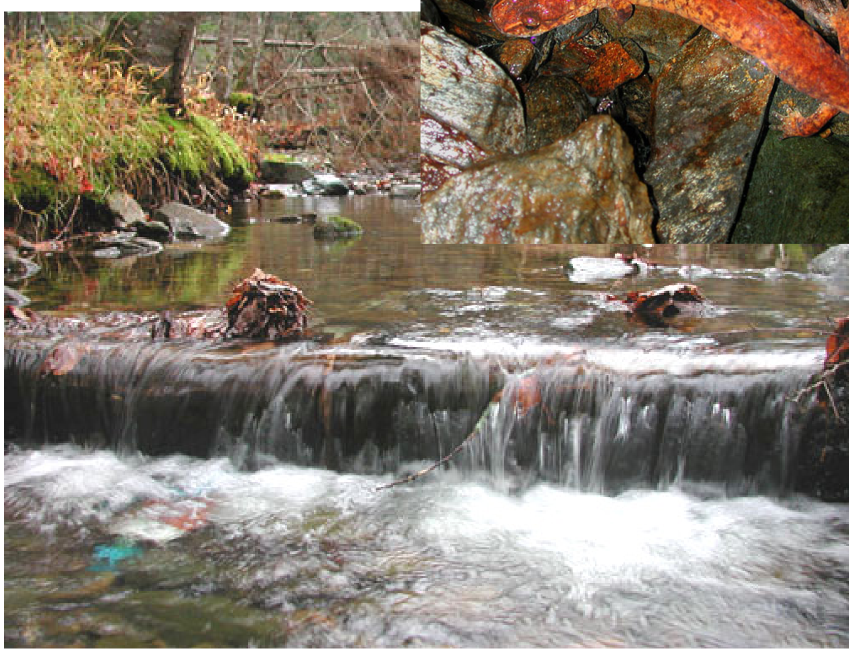




Northern
RESEARCH STATION
USDA Forest Service

Stream wood and the structure and function of stream ecosystems

- Globally – important role of stream wood widely recognized
- Two international conferences in the last decade
- Management ahead of research – use of wood to restore and improve habitat in Europe and North America for the last 100 years

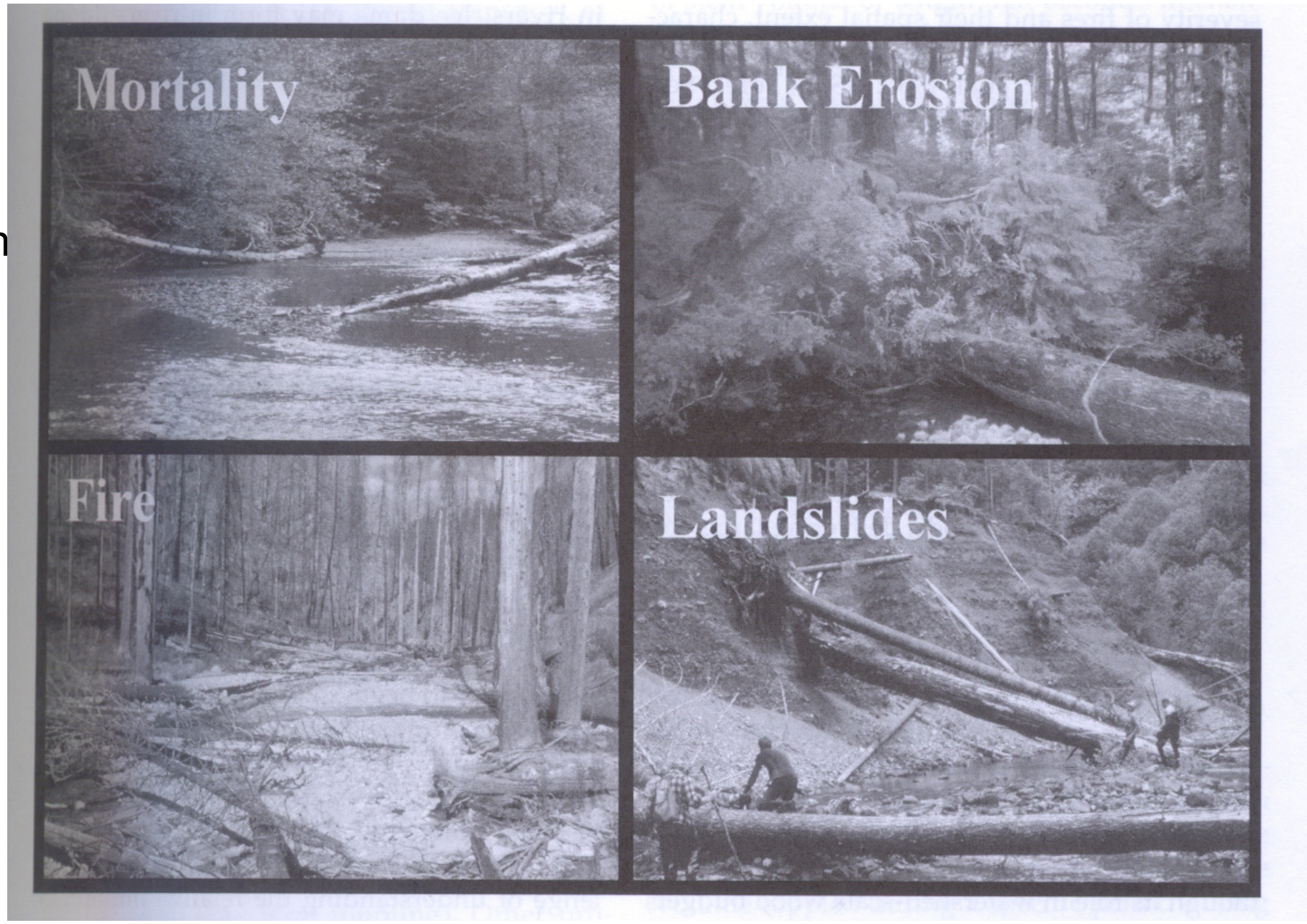
Structure of the Presentation

- Recruitment, Fate, and Ecological Role of Wood in Streams and Rivers
- Ecoregional Considerations
- Integrating Management and Research in the 21st Century

Forest Dynamics and Wood Recruitment

Chronic – single-tree mortality associated with self-thinning (suppression mortality), senescence; channel migration

Episodic – blowdowns; hillslope failures; insect outbreaks; fire



From Benda 2003

Forest Dynamics and Wood Recruitment

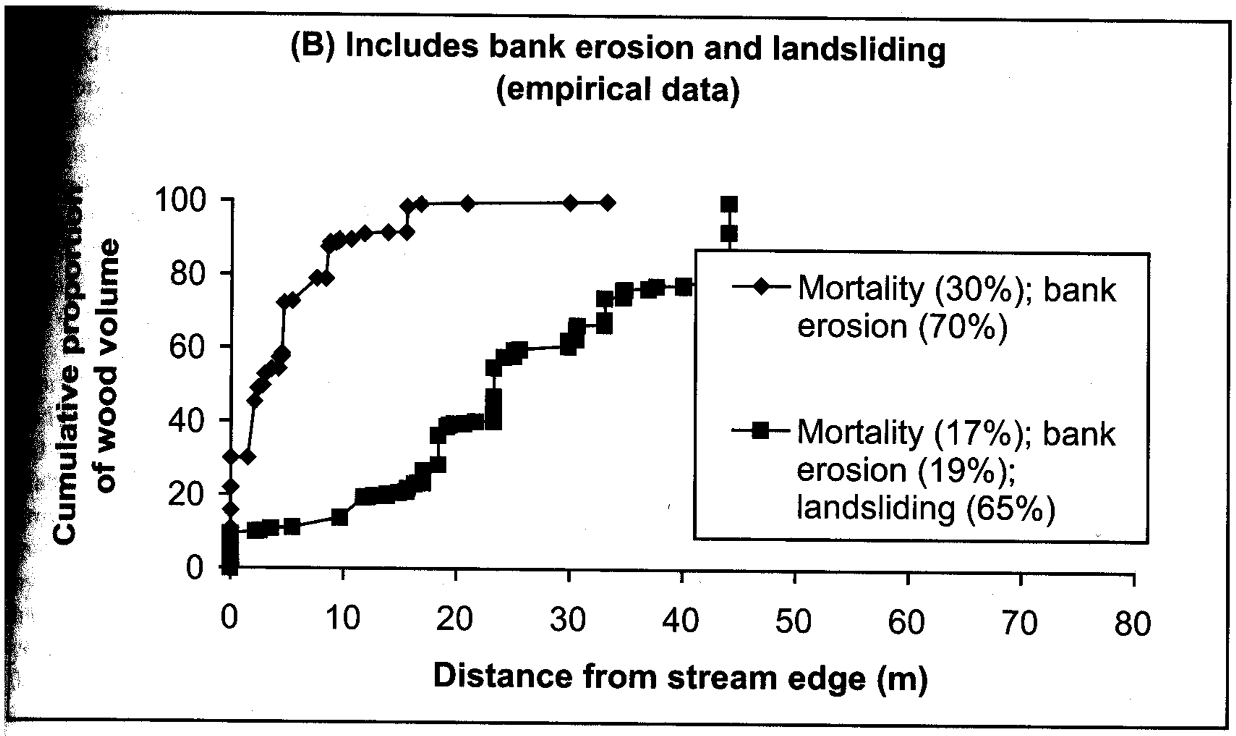
Distance from stream from which wood is recruited linked to recruitment mechanisms

- Bank erosion and individual tree and snag fall

1 -2 tree lengths

- Hillslope failures and mass-wasting

Longer distances



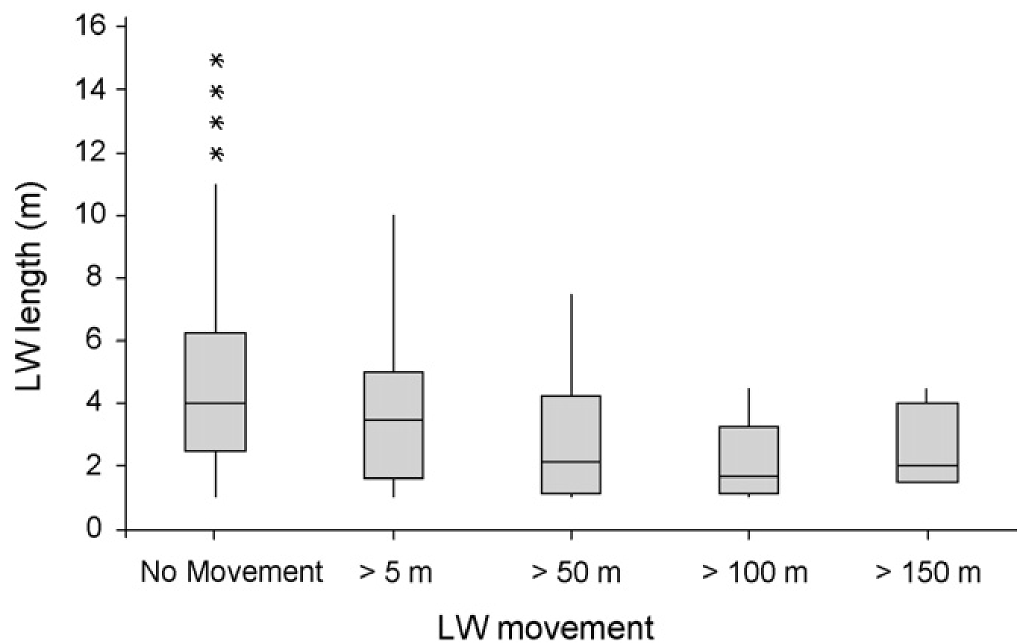
Wood transport, loss and retention

- Fluvial transport

threshold values for movement based on stream and piece size

If pieces are above a threshold size they are stable

Presence of rootwads greatly increases stability



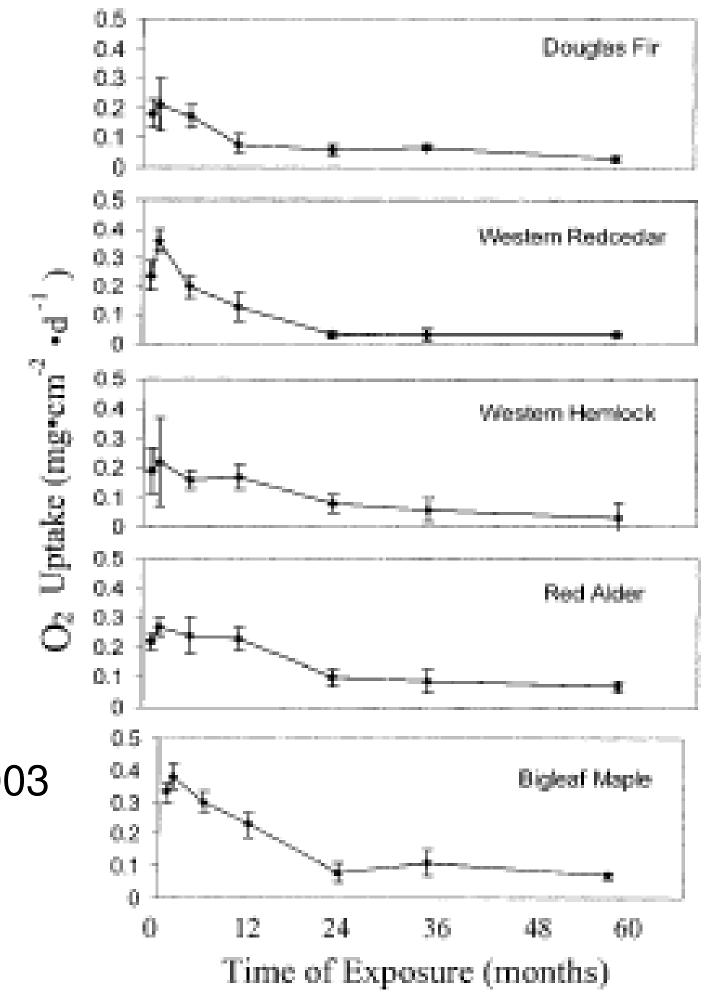
Wood transport, loss and retention

Decay as a component of loss

- Wood decays much more slowly in water then it does on land
- Major differences between tree species in decay rates

Trees	Decay Rates in Water
Hemlock	0.010
Balsam Fir	0.0105
Oaks	0.018
Maples, Beech	0.048

From Bilby 2003



Wood distribution and dynamics

- Longitudinal patterns

For a given tree size distribution:

From headwaters to large rivers

- Wood loads decrease
- Change from random spacing (individual logs and pieces) to highly clumped (jams)

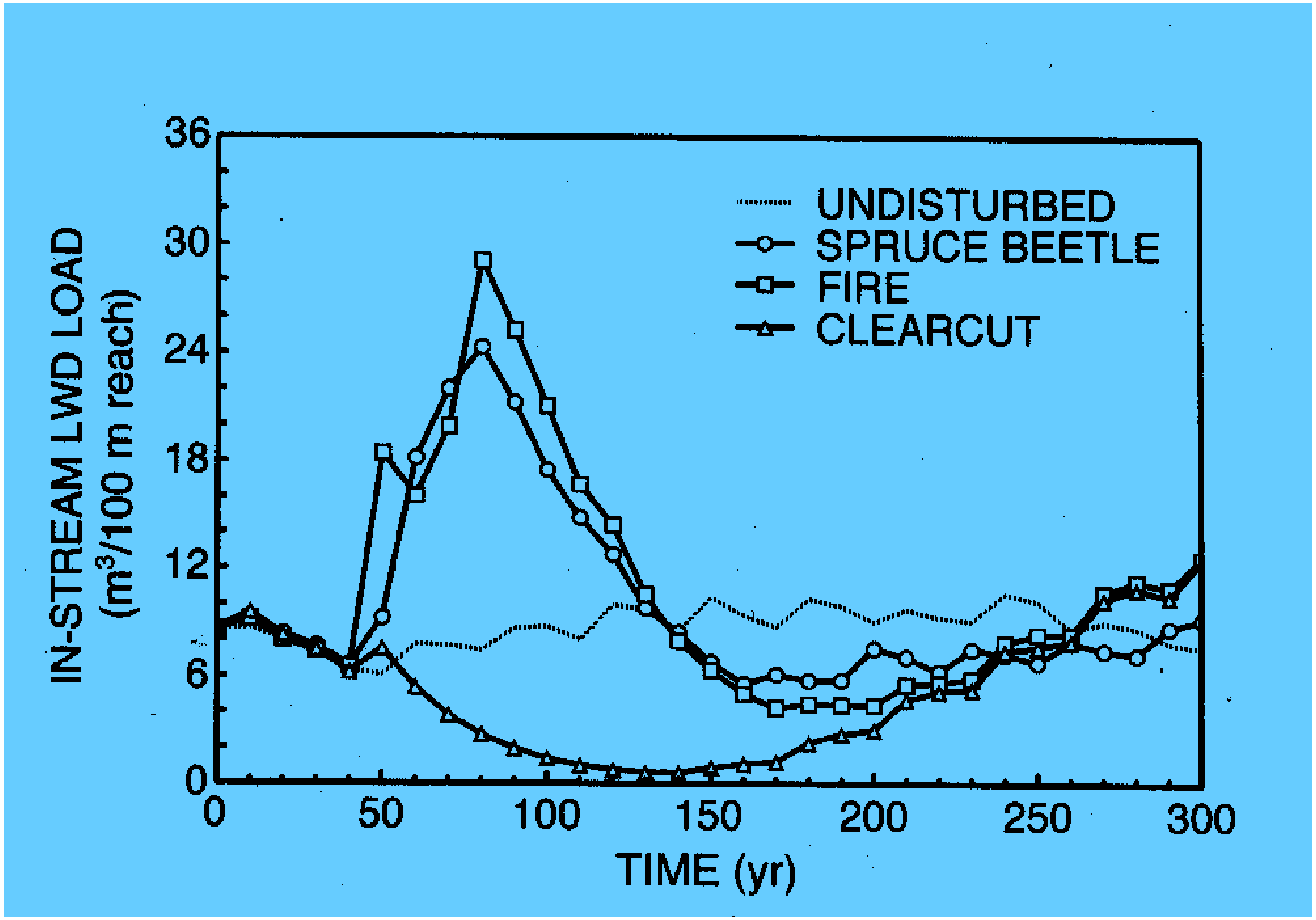
Wood distribution and dynamics

Changes over time

Long time scales

- Takes a long time for existing wood to leave the channel (except if its removed)
- Takes a long time for wood to recruit (complex series of stochastic and episodic processes)

From Bragg 2000



Effects of Forestry and Land Use Change

- Water Yield and Flow Variability
- Nutrient Loss
- Fine Sediment
- Temperature
- Light
- **Wood Regime**

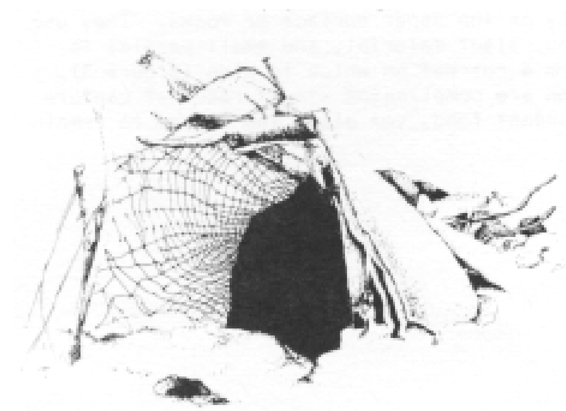
years

decades

centuries

Wood as habitat

- In low-gradient rivers with fine, mobile beds (as well as on lakeshores) wood in and of itself provides key habitat
- Shelter (particularly complex wood structures)- critical fish habitat
- Hard, stable substrates (required by sessile invertebrates)
- In southern rivers, snags compose a very small fraction of total benthic area, but account for a majority of invertebrate production



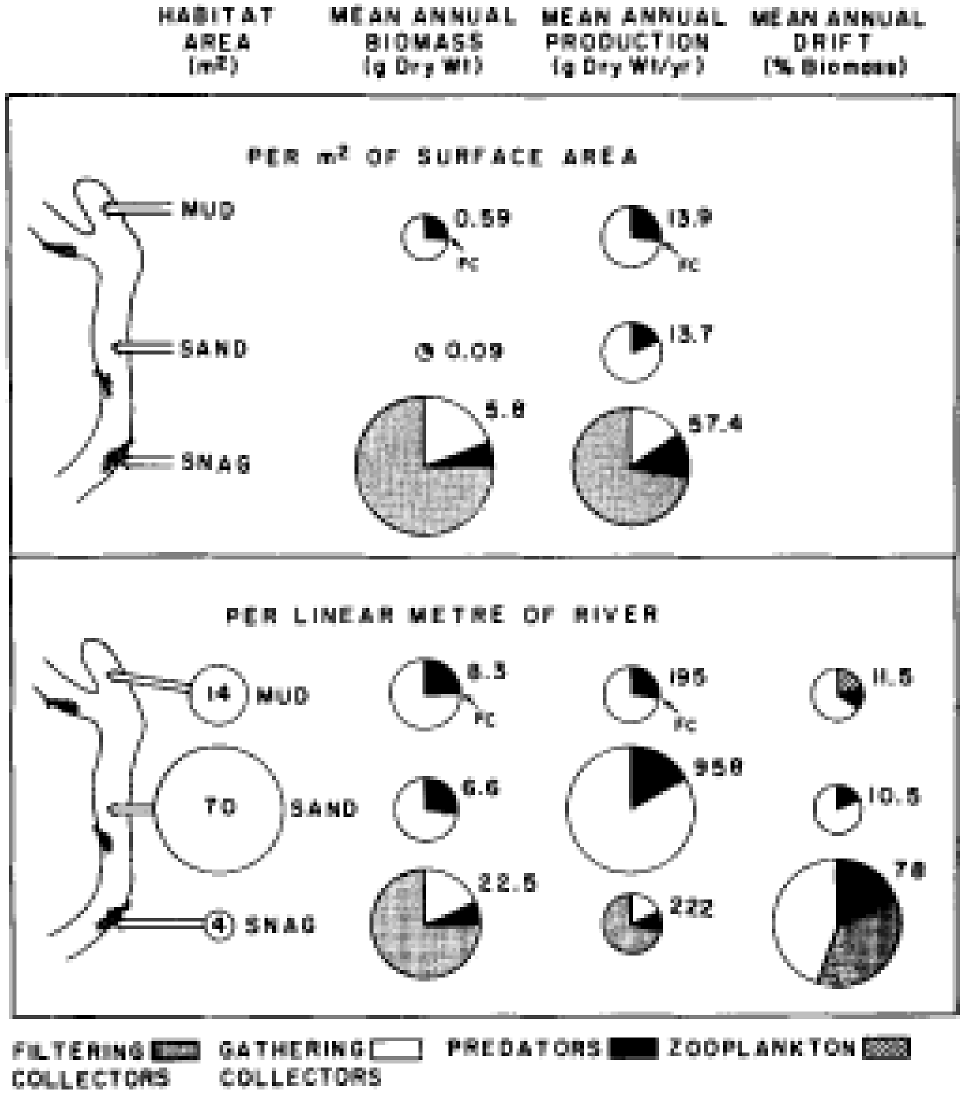


Figure 1. Mean annual invertebrate biomass, production and drift from the three major habitats in the Satilla River. The top of the figure presents biomass and production per surface area of habitat. At the bottom, the biomass and production are corrected according to the relative amounts of each habitat (m²/linear metre of river).

Benke et al. 1985

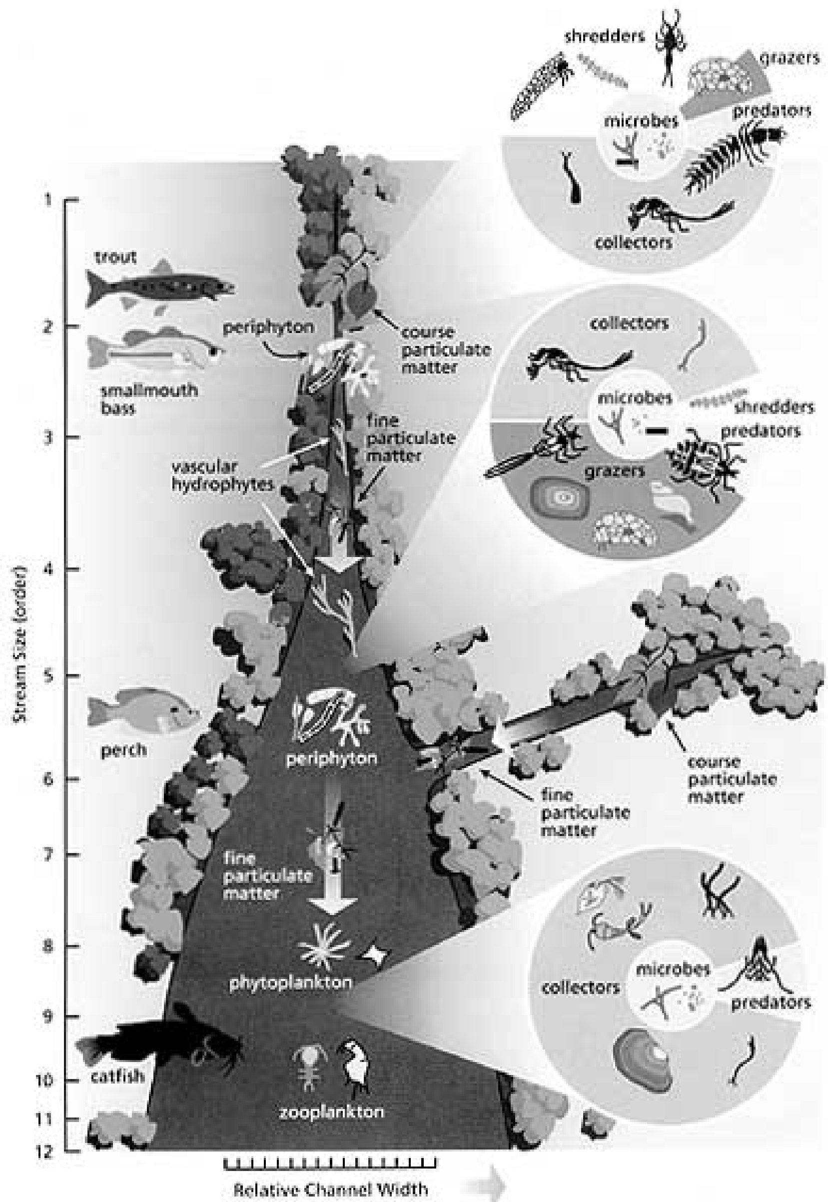
Wood as a geomorphic agent

- In coarse-bottomed streams, the primary role of large stream wood is as a geomorphic agent
- Pool frequency, volume, and quality
- Habitat heterogeneity
- Bank stabilization and erosion control
- Sediment storage

Wood and stream ecosystem paradigms

Conceptual models of stream ecosystems

River Continuum



www.edwardsaquifer.net/images/woody_debris.jpg
Image may be subject to copyright.
Below is the image at: www.edwardsaquifer.net/sariver.html

Wood and stream ecosystem paradigms

Conceptual models of stream ecosystems

River Continuum

**Nutrient Spiraling

Nutrient Spiraling

- In forests – nutrients cycle (make a circle)
- In streams – advection (downstream flow) causes nutrients to spiral

Distance a nutrient molecule travels before being taken up by biota = <u>spiraling length</u>

Water velocity is a major determinant of spiraling length

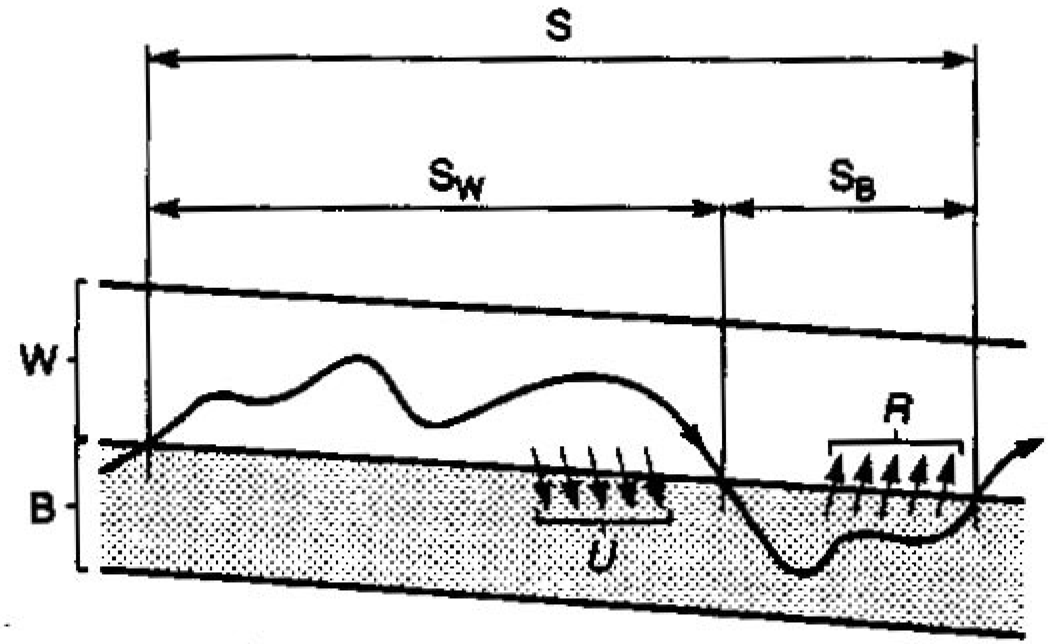
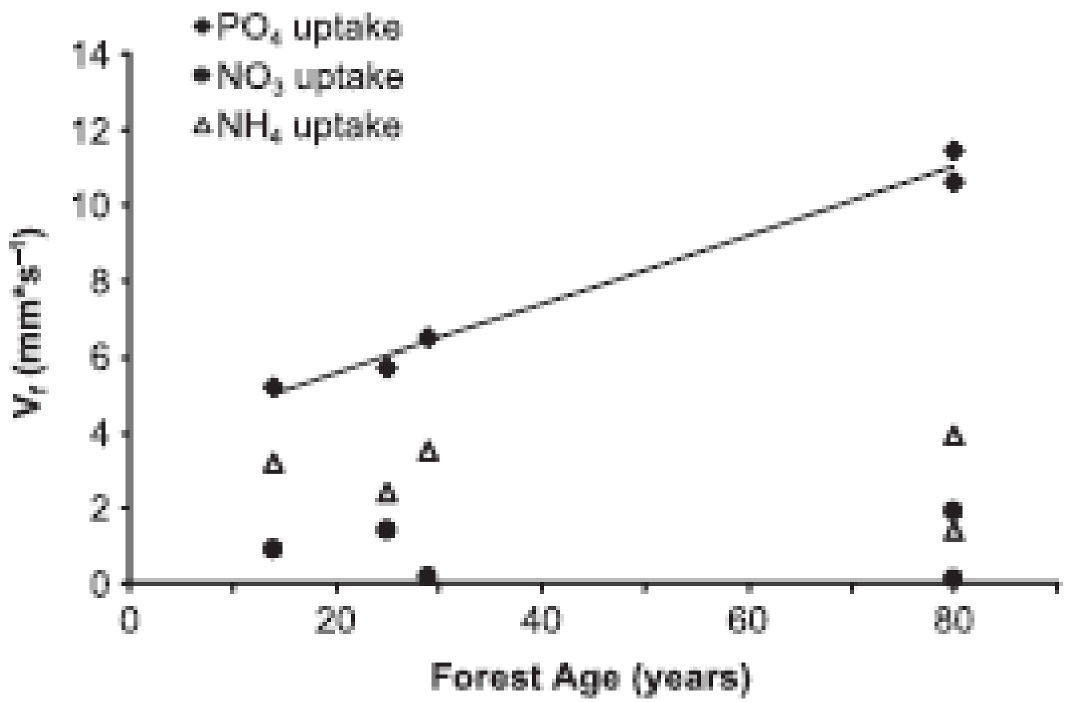


FIGURE 13.5 Two-compartment nutrient spiraling model. The spiraling length S is the average distance a nutrient atom, such as phosphorus, travels downstream during one cycle. A cycle begins with the availability of the nutrient atom in the water column, includes its distance of transport in the water (S_w) until its uptake (U) and assimilation by the biota, and whatever additional distance the atom travels downstream within the biota (S_B) until that atom is eventually re-mineralized and released. (Modified from Newbold, 1992)

Effects of LWD on nutrient spirals

- Increased transient storage = tighter spirals = higher uptake velocities = longer retention (reduced export rates)



Warren et al. 2008

Wood and Biodiversity

- Not just salmonid fishes!
- Habitat diversity = species diversity
- Potential for complex interactions

Ecoregional Setting

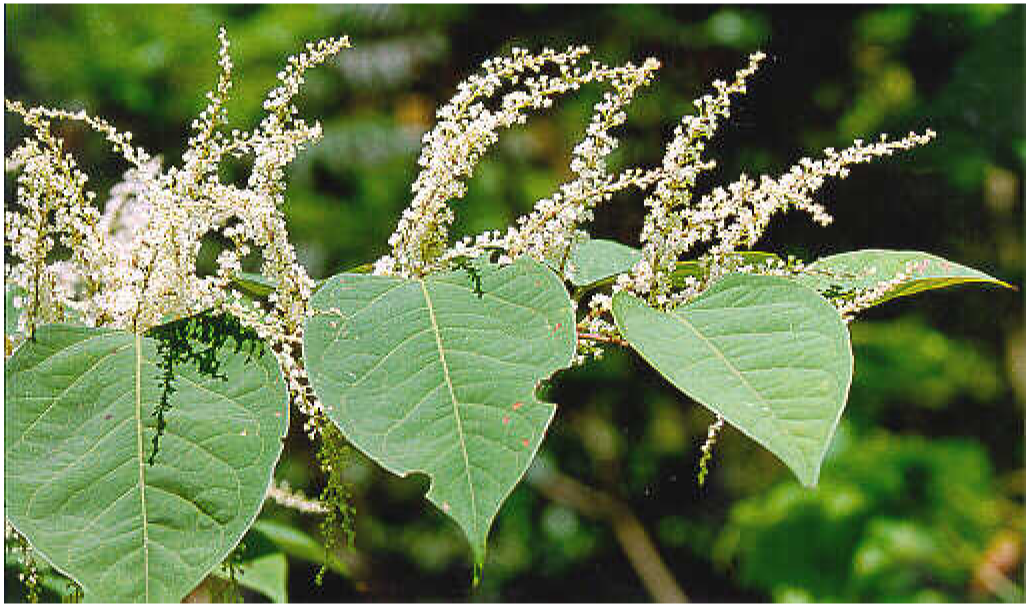
- New England and the northeast

Ecoregional attributes influencing the role of wood in aquatic ecosystems

- Mesic, north temperate ecosystems
- Even distribution of precipitation, but uneven distribution of streamflow
- Glacial influence
- Tectonically inactive
- Old, tired rocks
- Early industrialization based on water power – reduction in heavy industry
- High density of dams and barriers
- Atmospheric deposition, base cation depletion,

Invasions, Extirpations, Restorations

- **Vegetation Change**
- Loss of American Chestnut
- Imminent loss of Eastern Hemlock
- Red Spruce decline
- Host of riparian invasives

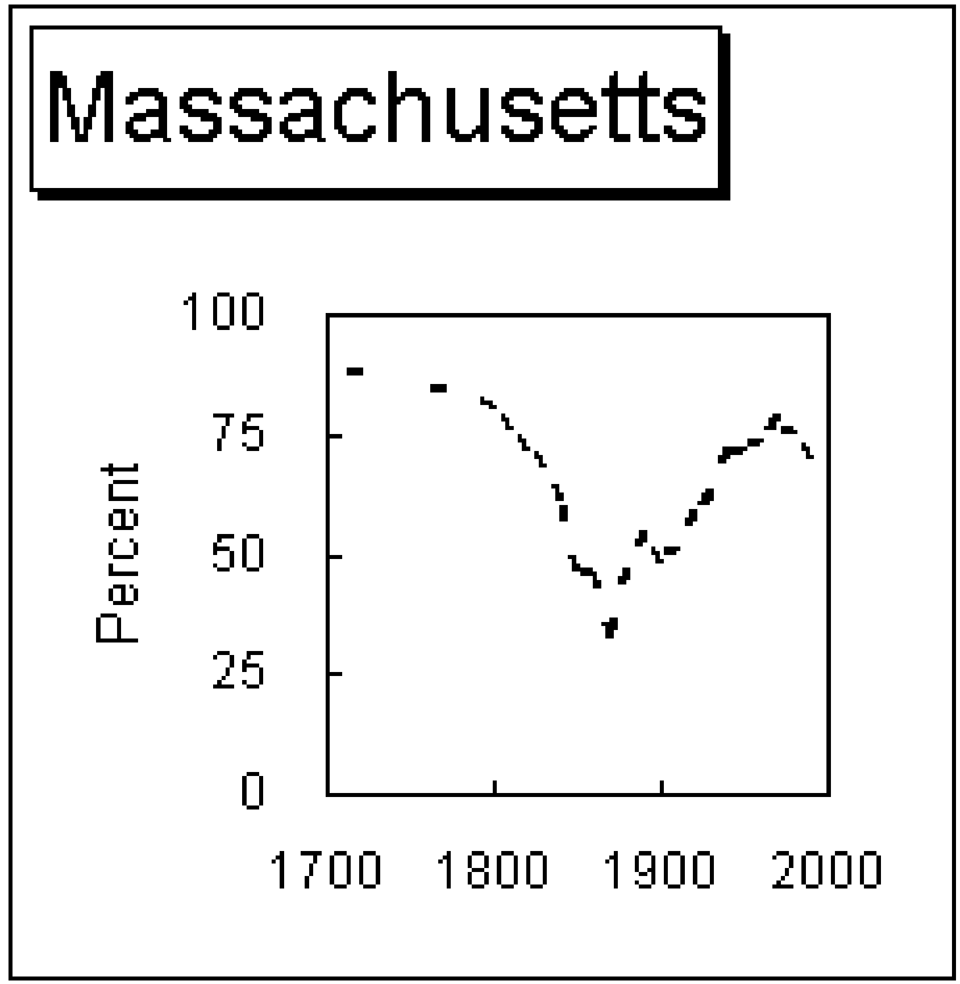


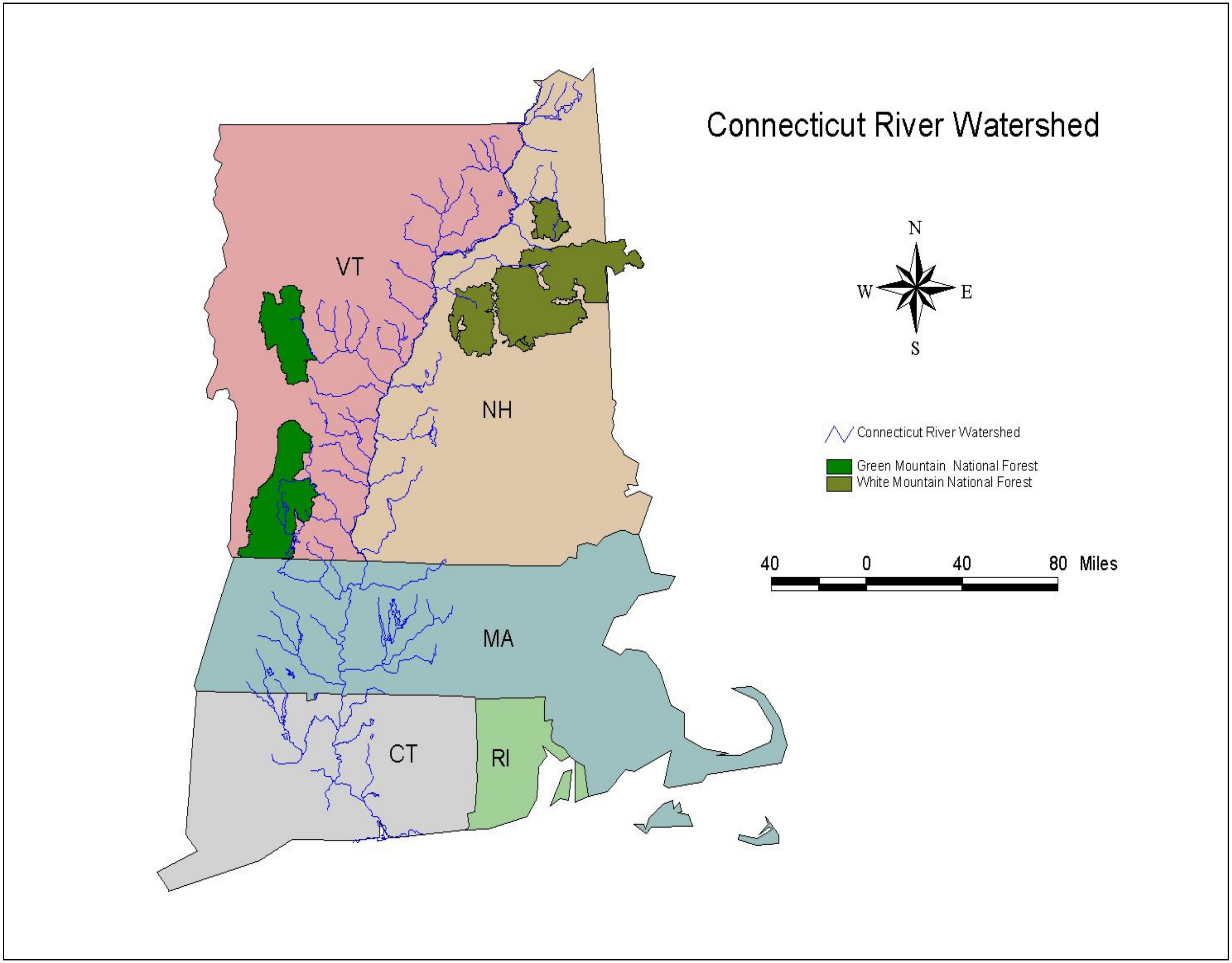
Invasions, Extirpations, Restorations

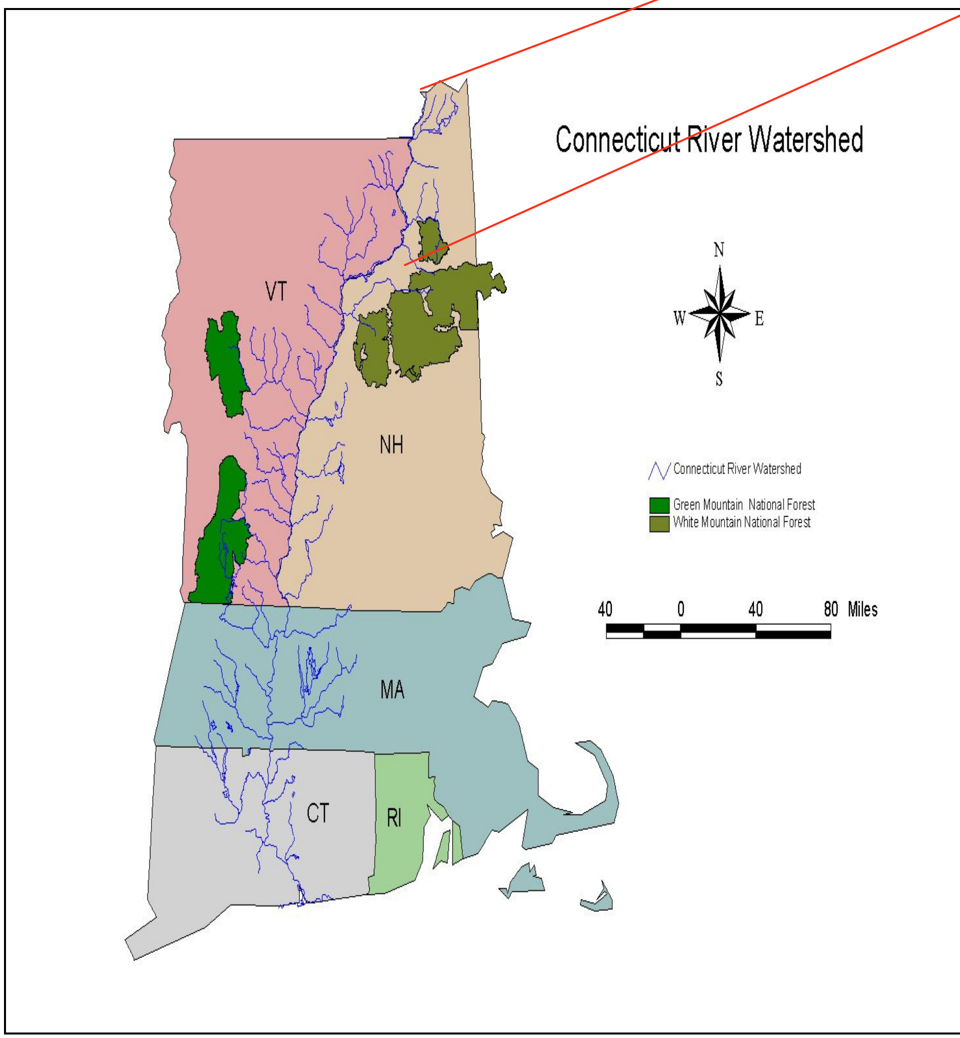
- **Faunal Change**
- Introduced trout and black bass
- Loss and re-establishment of North American beaver, moose
- Decline, loss, restoration of migratory fishes

The Northeast as a Model

- Given riparian protections and BMPs, riparian areas in general may echo reforestation trends

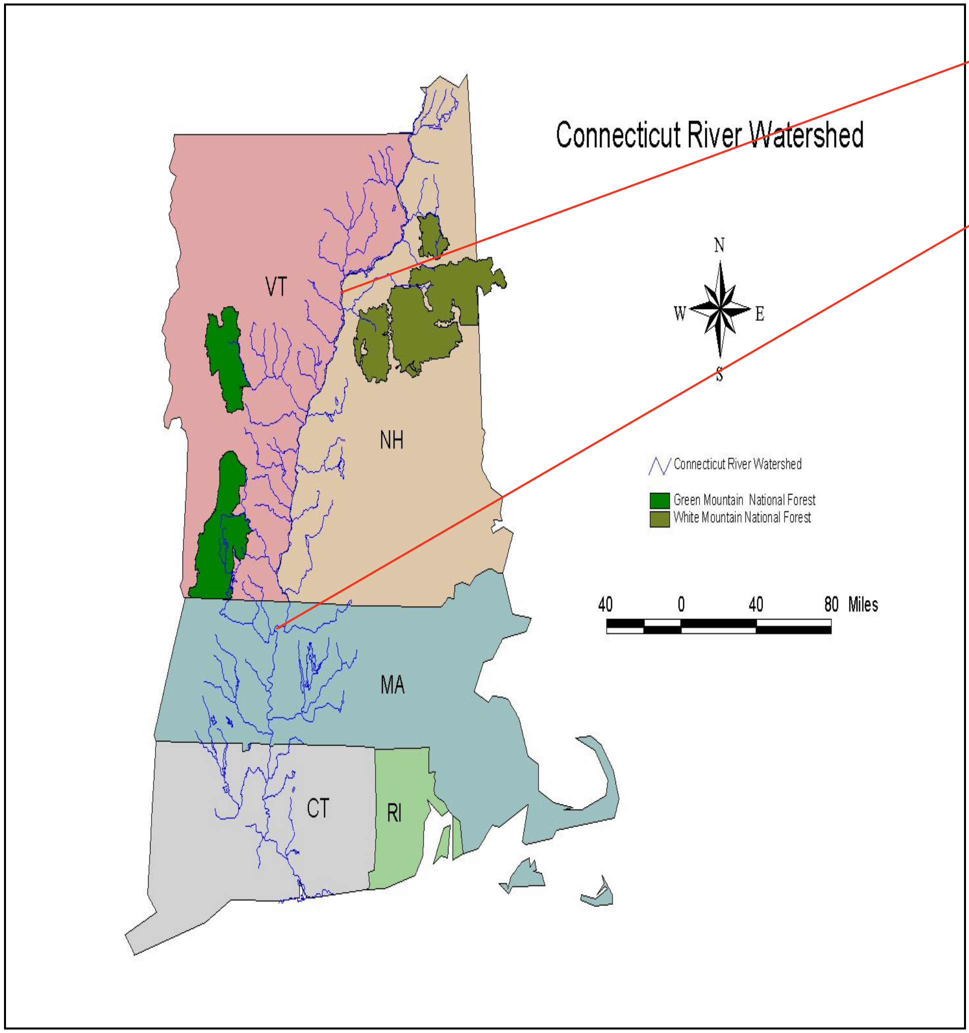



Connecticut River Watershed
N
W
E
S
VT
NH
MA
CT
RI
Connecticut River Watershed
Green Mountain National Forest
White Mountain National Forest
40
0
40
80
Miles



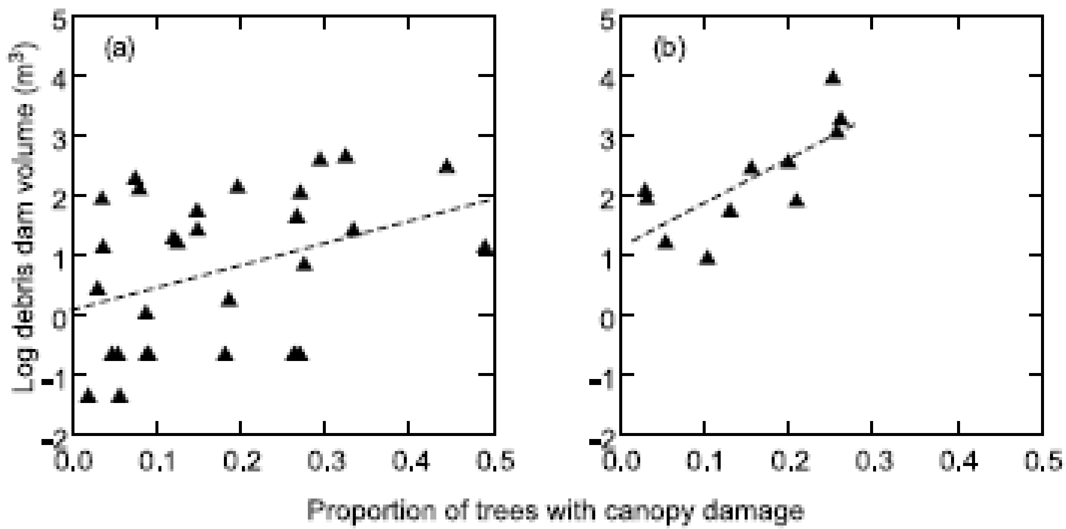
Boreal Forest
-Spruce, fir
-Fire, insect outbreaks

Conversion to industrial timberlands



Northern Hardwood Forest
-Maple, birch, beech
-Wind and Ice

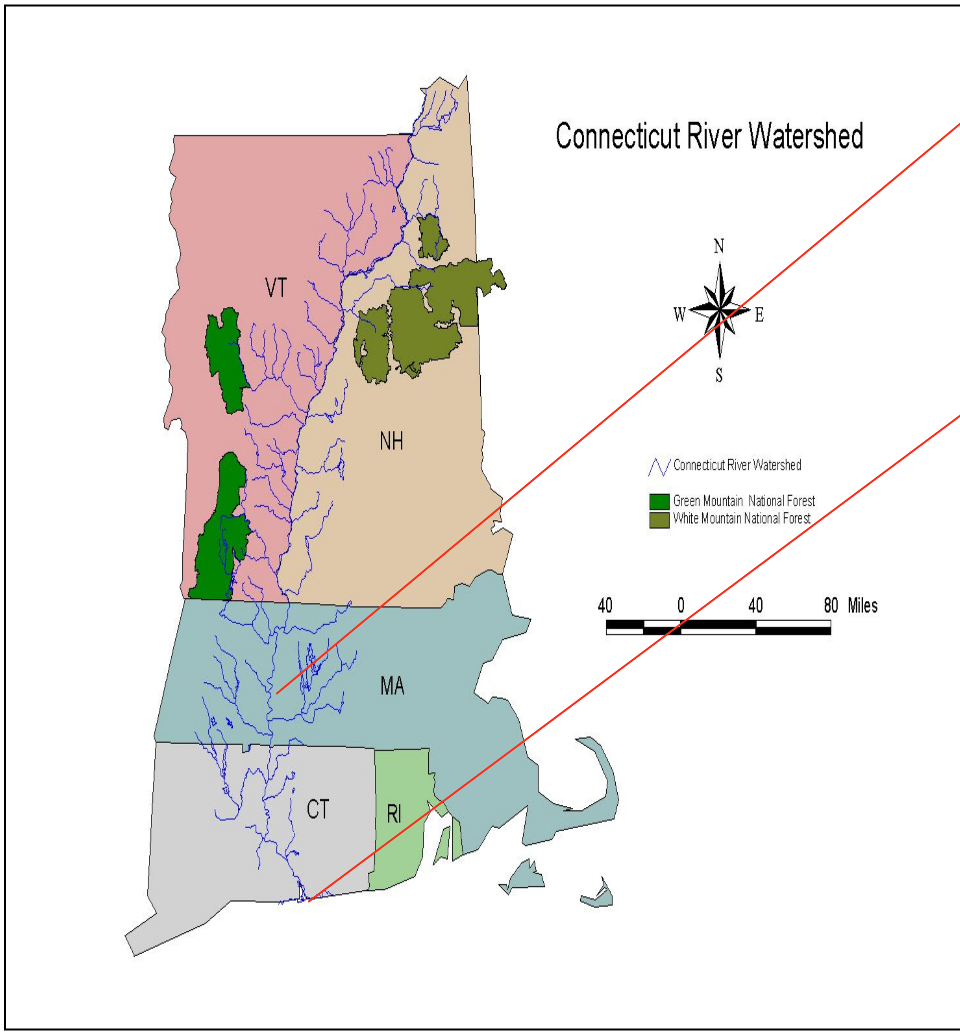
Regeneration of mature forest

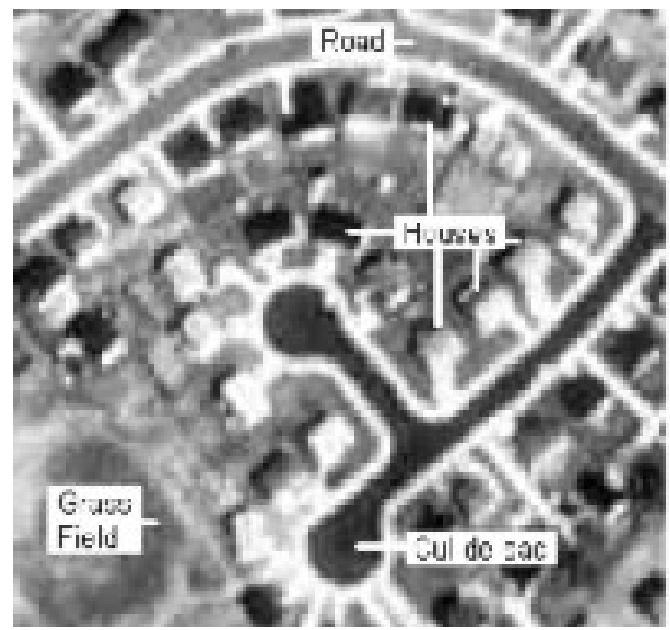


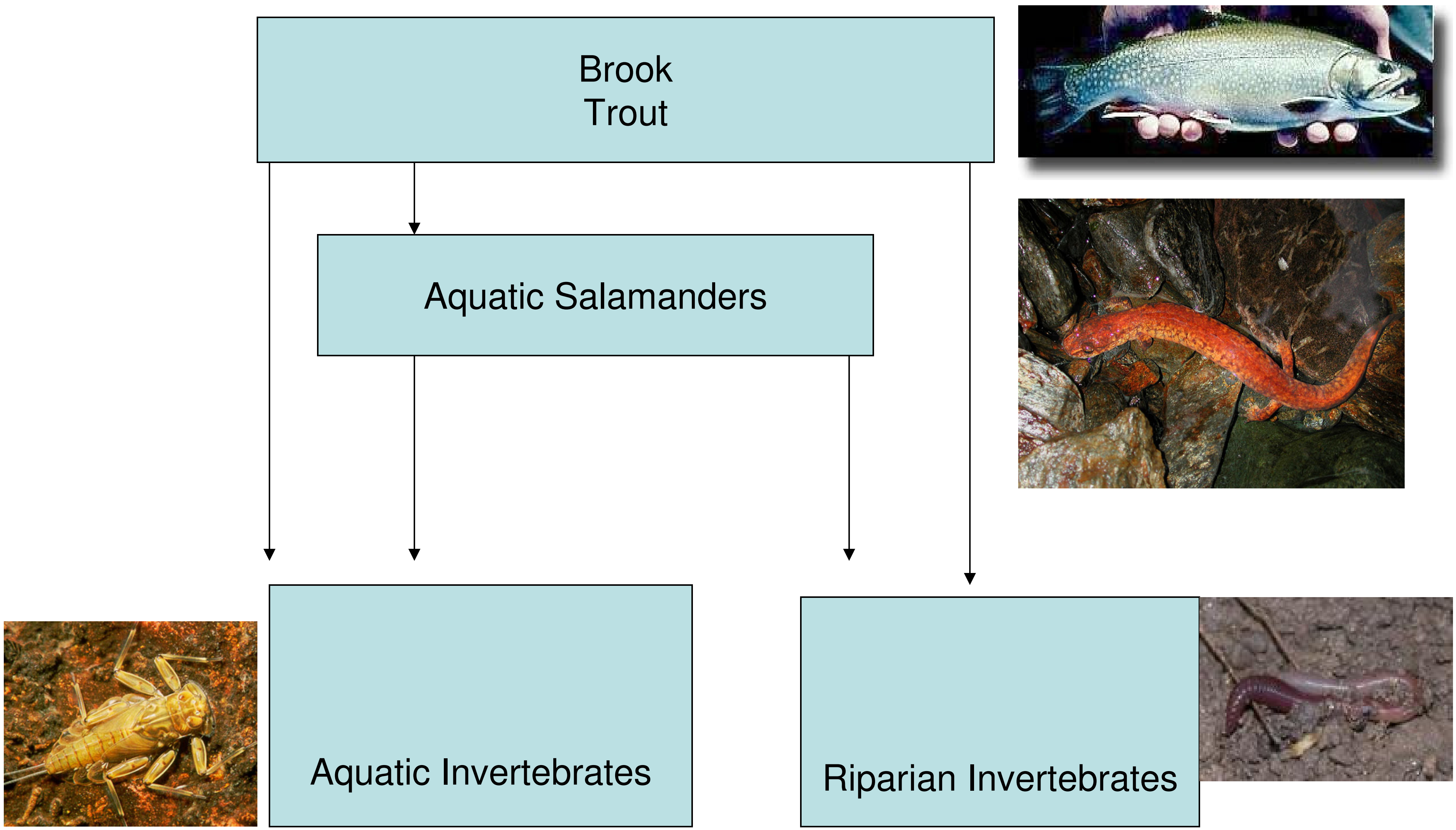
From Kraft et al. 2002

Oak-Hickory Forest
-- Hurricanes

Residential and Commercial Development






Brook Trout
Aquatic Salamanders
Aquatic Invertebrates
Riparian Invertebrates

Wood in Streams in the Northeast

- General Considerations

- Current conditions

Some of the lowest observed wood loads (Magilligan et al. 2007 in coastal Maine)

- Limitations on the role of wood due to:

Tree size limitations (current and future???)

Channel and valley morphology

Table 4
Channel dimensions at the 2-year bankfull discharge

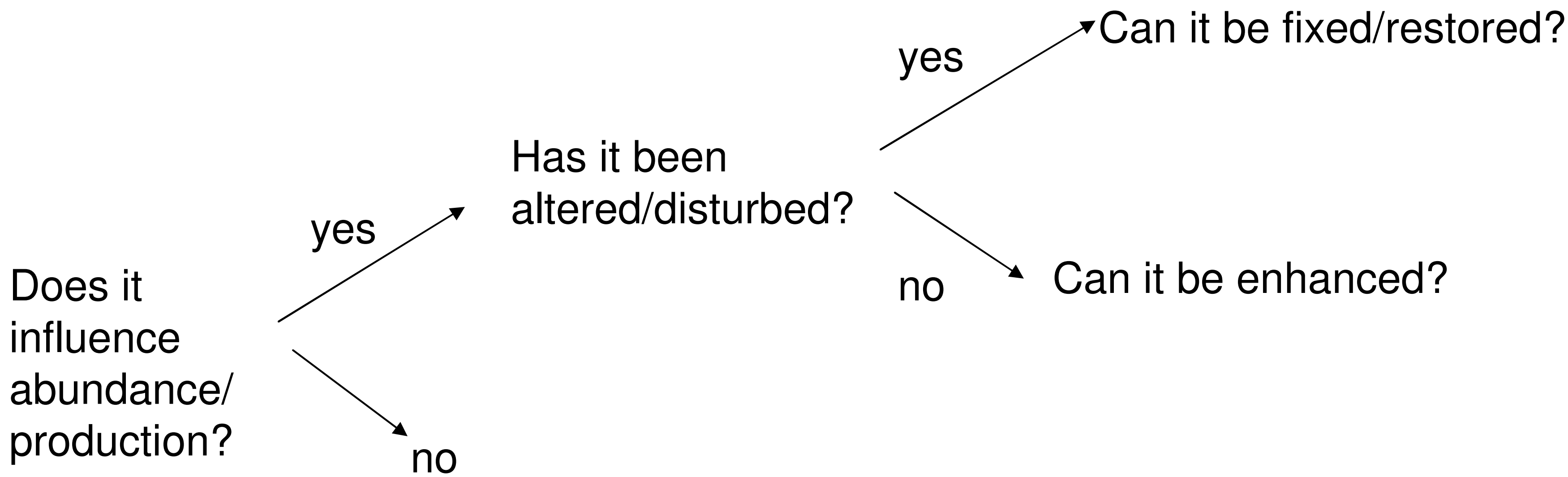
River	Drainage area (km^2)	Q_2 ($m^3 s^{-1}$)	Bankfull width (m)	Bankfull depth (m)	Ratio of bankfull depth to mean LWD diameter[a]
Machias River at Whitneyville	1186.22	167.54	54.41	3.27	16.37
Narraguagus River at Cherryville	587.93	110.26	39.25	1.75	8.77
Sheepscot at N. Whitefield	375.55	54.65	23.09	1.25	6.23
Pleasant River at Epping	156.95	22.17	23.10	1.14	5.69
Old Stream near Wesley	75.37	12.24	19.34	0.65	3.23
Ducktrap River at Lincolnville	37.30	10.91	10.43	0.87	4.33

[a] Assumes mean LWD diameter = 0.2 m

Integrating Wood Management and Research

- Goals, Targets, and Priorities
- Monitoring and Adaptive Management

In North America, fish habitat and fish population enhancement has been at the forefront of wood addition/restoration projects



Species requirements paradigm

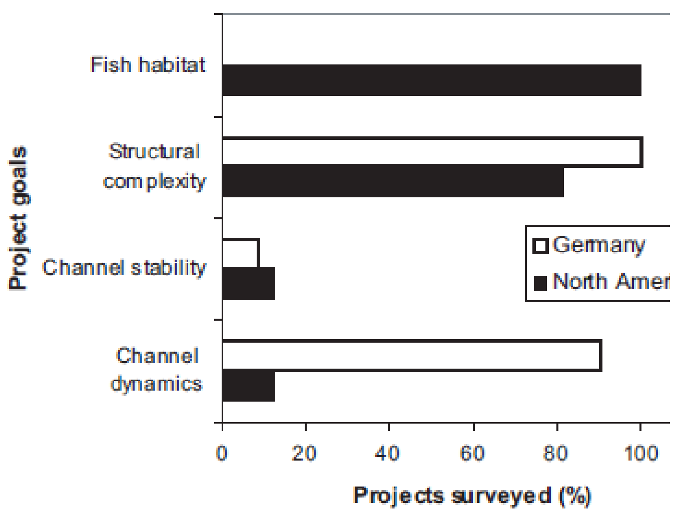


FIGURE 2. Goals of restoration projects in North America (n = 16) and Germany (n = 11).

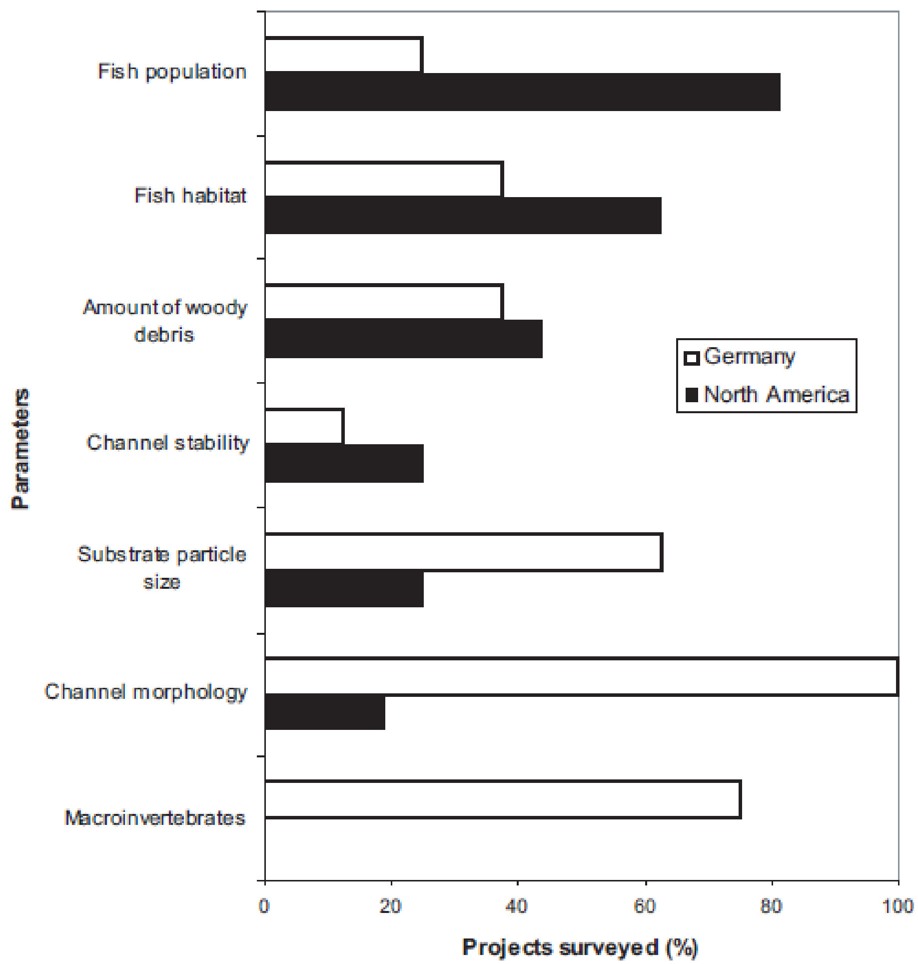


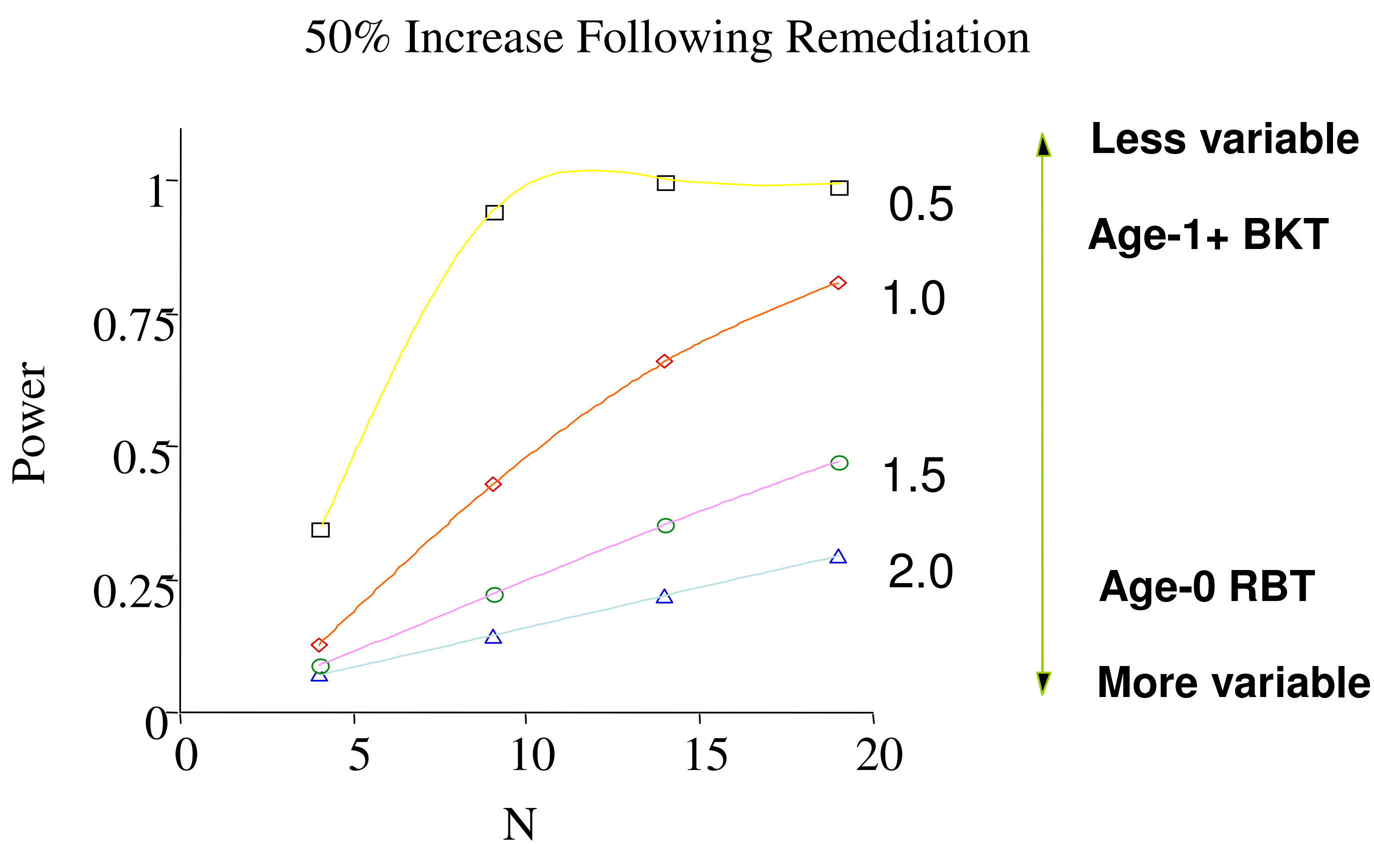
FIGURE 7. Parameters to measure success of wood additions in North America (n = 13) and Germany (n = 8).

From Reich et al. 2003

Species-Requirement Paradigm-Problems

- Difficult to detect effects
- Difficult to scale up from effects on individuals at specific life-history stages in specific sites/contexts to long-term effects on populations across the region
- Doesn’t account for community/ecosystem/basin-wide impacts

Relationship Between Study Duration, Population Variability, and Statistical Power to Detect Effects of LWD



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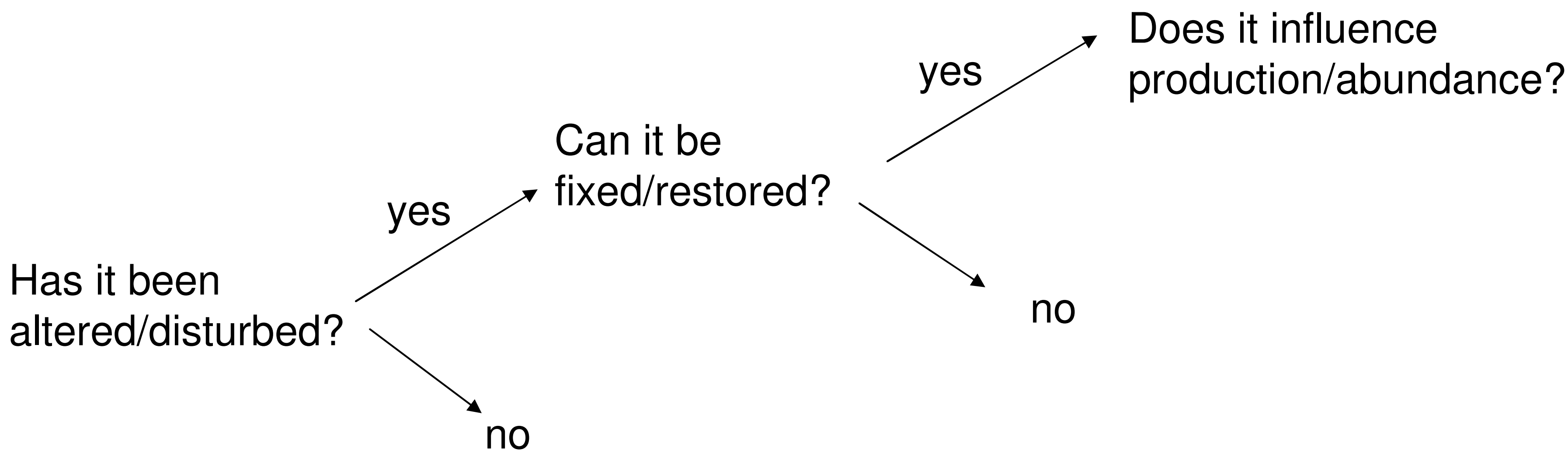


Process restoration paradigm

The ‘natural wood regime’

- Parallels to the ‘natural flow regime’ concept (Poff et al. 2004)
- Natural regimes and natural dynamics as the benchmark
- Still won’t negate the need to assess impacts on species of concern

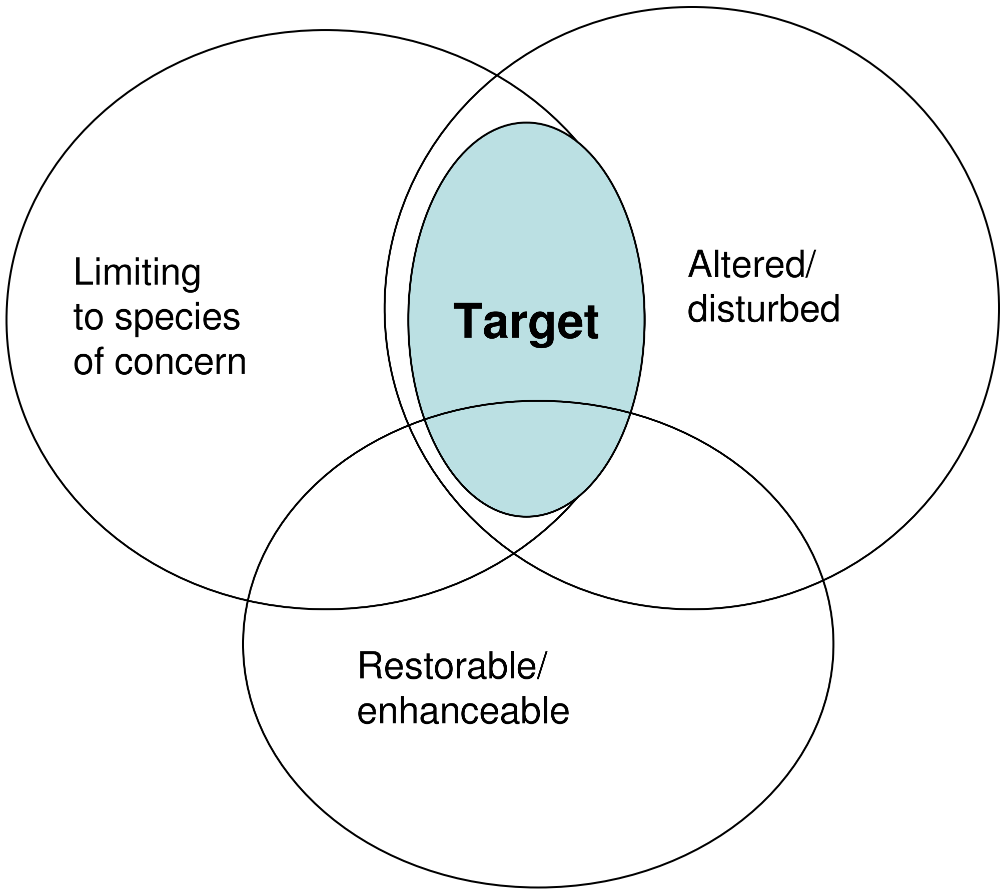
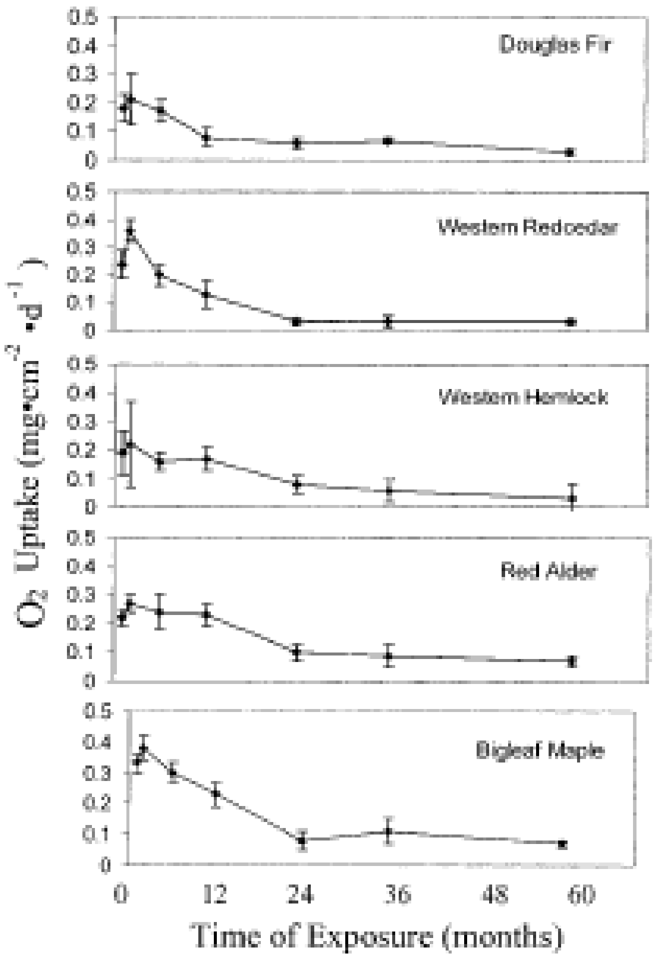

Limiting
to species
of concern
Target
Altered/
disturbed
Restorable/
enhanceable

Figure 4



From Bilby 1999

Longitudinal variation and the role of stream wood

Effects on stream morphology and physical habitat

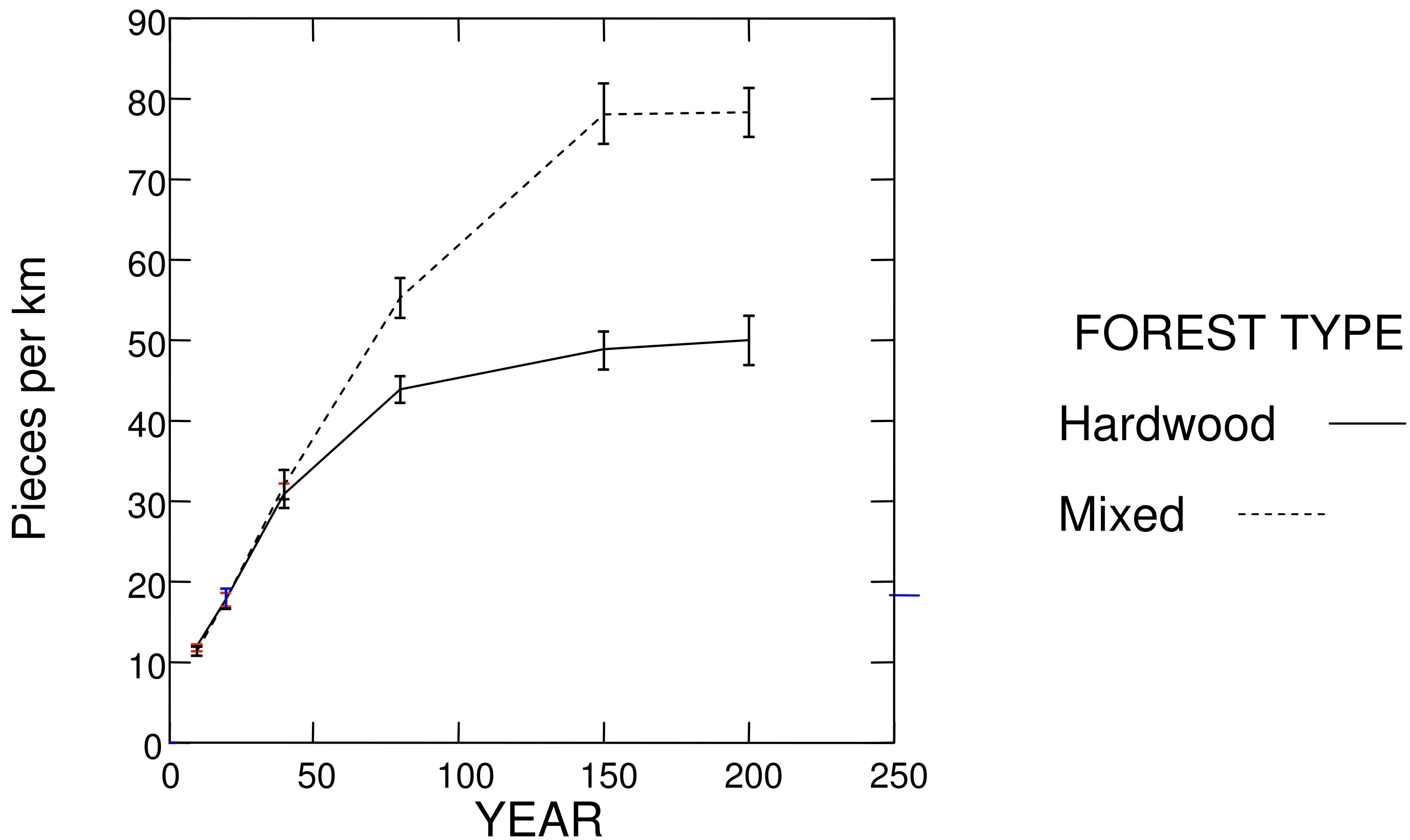
High gradient coarse substrate streams – Effects on channel form and sediment dynamics

Low gradient fine sediment

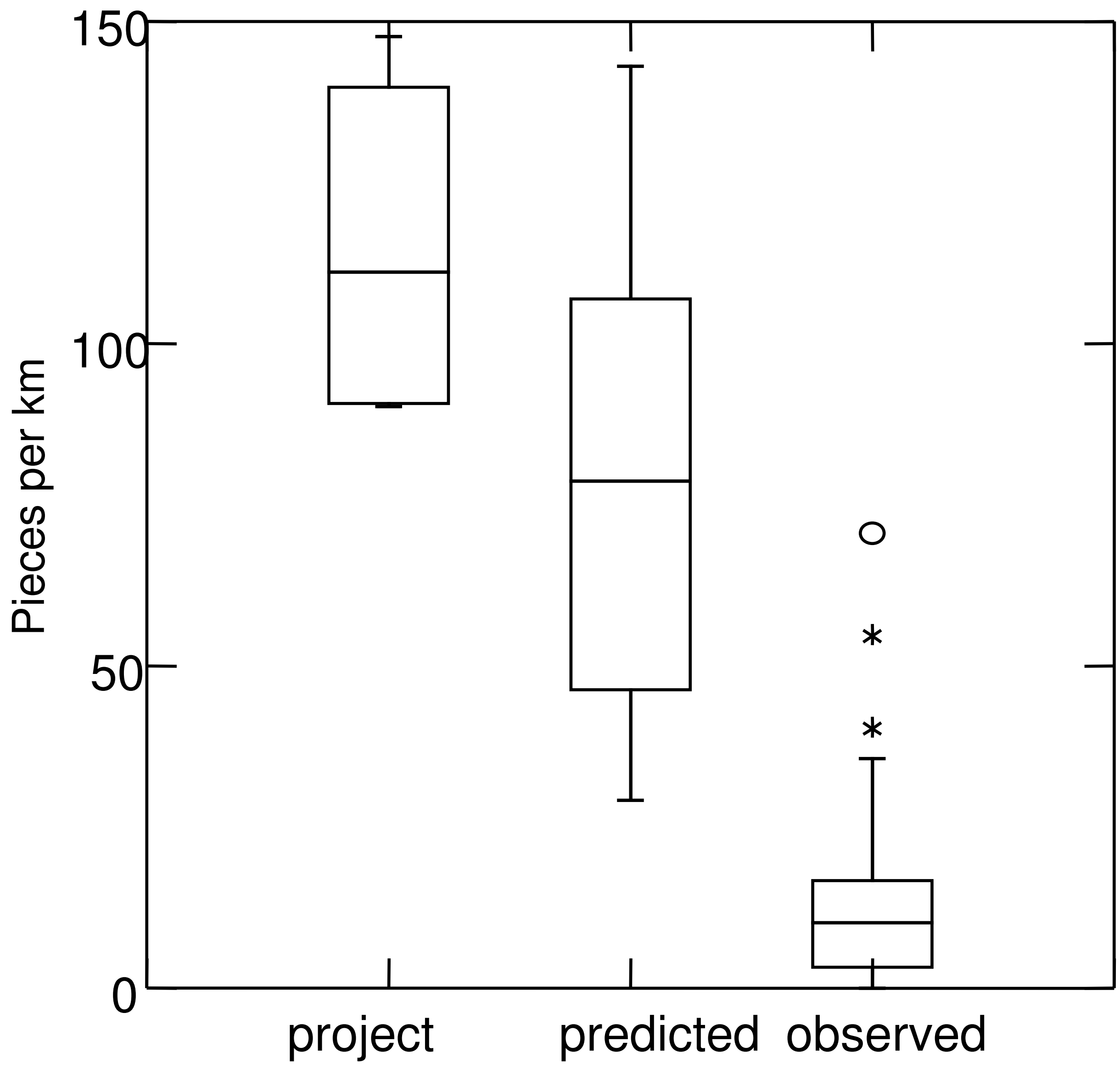
gradient

Substrate size

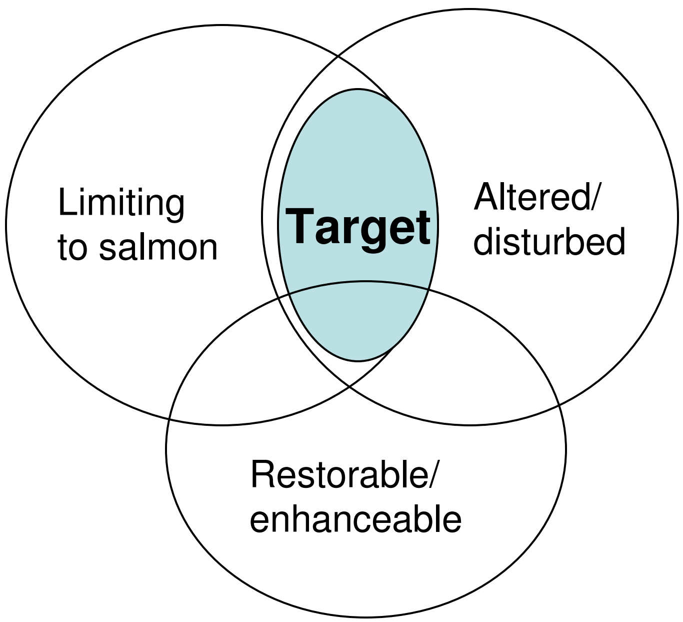
The ‘natural wood regime’



Pieces per km
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
YEAR
FOREST TYPE
Hardwood
Mixed



150
100
50
0
Pieces per km
project
predicted
observed


Limiting
to salmon
Target
Altered/
disturbed
Restorable/
enhanceable